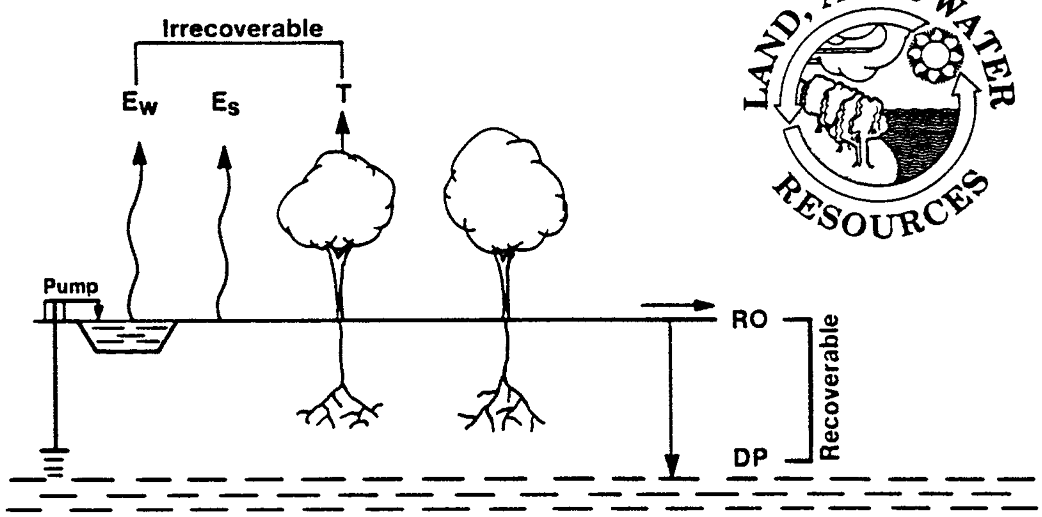
SUMMARY AND CONCLUSIONS

AGRICULTURAL WATER CONSERVATION IN CALIFORNIA, WITH EMPHASIS ON THE SAN JOAQUIN VALLEY



by
David C. Davenport and Robert M. Hagan

October 1982

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ABSTRACT

There is a need to reduce California's net water deficit which is presently reflected in the San Joaquin Valley mainly as groundwater overdraft. New water development has become more difficult and the State Water Project does not now have facilities to meet its contractual water supply commitments for the future. Divergent views on the potential and the role of agricultural water conservation in alleviating the state's present and projected net water deficit often arise out of misunderstandings of the uses and destinations of agricultural water.

This report attempts to clarify these issues by: 1) distinguishing between water losses that are recoverable for reuse, and water losses that are irrecoverable, thereby precluding their availability for further use in meeting competitive water demands; 2) providing background information on the sources of water and its distribution by water agencies, and on irrigated agriculture in the San Joaquin Valley; 3) describing water conservation actions that are a) theoretically possible and b) presently practiced in irrigated agriculture; and 4) describing the numerous impacts, both on-farm and off-farm that are associated with water conservation actions.

In the light of the concept of distinguishing between recoverable and irrecoverable water losses, the role of agricultural water conservation is described in statewide perspective to determine its significance for reducing the state water deficit, with due regard to impacts on the agricultural industry and on environmental values.

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CONTENTS OF COMPLETE REPORT

(Copies of complete Report are available from Dept. of LAWR,
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SUMMARY

The Problem

Poorly distributed precipitation, both seasonally and geographically, and increasing competition between agricultural, environmental, municipal, and industrial demands, have made water a complex social, political and economic issue in California. Since irrigated agriculture accounts for 85% of the state's applied water and is sometimes accused of being a major water waster, this report focuses on the effects of water conservation in agriculture, with particular emphasis on the San Joaquin Valley (SJV), and on the relation of conservation to California's water budget.

The federal Central Valley Project (CVP) is presently meeting its contractual commitments and some developed CVP water, as yet uncontracted, may become available to agriculture. On the other hand, present facilities of the State Water Project (SWP) are inadequate to meet the 4.2 million acre-feet (MAF) of contractual commitments in the near future, and new water development is becoming increasingly difficult.

Water conservation is suggested by some as being a totally adequate solution to overcoming the state's water deficit (now reflected mainly as groundwater overdraft). Others feel conservation is only a partial solution, and still others believe that past and present conservation practices have reached their practical limits, so the state's projected deficit can only be met by further development and diversion southward of northern California water. These divergent views occur partly because of special interests, but mainly because of 1) misunderstandings over the uses, reuses, and final destinations of water, and 2) disregard for the impacts of water conservation/development actions on economic and environmental factors. This report attempts to clarify these issues.

The Concepts

"Water conservation" has been defined in different ways and each definition can be variously interpreted. The term has several connotations including: prevention of damage, loss or waste; reduction in rate of use; reduced demand; and efficient use for the good of all. All of these definitions are acceptable, but what matters is the impacts of the conservation action 1) on *net* quantity of water saved and for whom (or for what), and 2) on economic, environmental and social interests such as agricultural production, instream needs and dependability of urban water supply.

To help in clarifying these impacts, it is necessary to distinguish between water that has been used one or more times and is either *recoverable* for reuse or *irrecoverable* because it evaporates or transpires to the air or flows to a highly saline sink or to a geologic formation from which recovery is not practical. (All water, of course, eventually returns through the hydrologic cycle.) For example, increasing irrigation application efficiency reduces deep percolation (DP) and runoff (RO) from the field, but it also reduces return flows by roughly the same amount so there is no net water savings. Under many conditions there could be a savings in pumping energy and in the quality of waters receiving return flows. On the other hand, a reduction in crop transpiration results in reduced *net* water demand because water lost to the air does not contribute to reuseable return flow. However, the price paid for reducing crop transpiration is almost inevitably a loss in crop production. Similarly, diversion of ocean-bound river flows would clearly curtail an irrecoverable water loss, but excessive diversion during the low-flow season often has adverse impacts on in-stream requirements.

Such distinctions between recoverable and irrecoverable water losses and recognition of the impacts of reducing them are emphasized throughout this report.

Background on Agricultural Water in the San Joaquin Valley (SJV)

Water sources in the SJV include: 1) relatively scant rainfall (particularly scant in the south and west), 2) surface water from local streams (on which many users have historical riparian and appropriative rights) and redistribution of "local" San Joaquin River flows, 3) imported water through interbasin transfers (Northern California water pumped via the Sacramento-San Joaquin Delta through the Delta-Mendota Canal and the California Aqueduct), and 4) groundwater which contributes to over 40% of applied water resulting in an overdraft of some aquifers. Most of the groundwater pumping is under the jurisdiction of individual users overlying the aquifers. Surface water for irrigation is mainly distributed to users at cost by local water agencies (such as Irrigation Districts, California Water Districts, and mutual water companies).

Each district is unique in its historic, geologic, geographic, water-source, political, and other characteristics. Therefore, pricing, management, and distribution policies vary considerably from district to district. Because of these unique characteristics, universal recommendations on agricultural water conservation actions cannot be applied. Thus, some older districts (organized before 1920) have unlined water distribution systems and, because favorable soil conditions enable groundwater recharge (from seepage water that is recoverable), they consider this to be a significant advantage for their areas. Many newer districts, on the other hand, do not overlie areas of readily recoverable groundwater. Such districts use lined canals or buried pipelines which improve conveyance efficiency and do not occupy arable land surface. Irrigation water, particularly groundwater available in the west side of the SJV, is generally of poorer quality than in the east side. Therefore, in those areas with higher salt levels, some additional water (over and above that needed to meet the crops' consumptive use) must be applied to leach salts from the crop root zone. The fraction of applied water used for leaching cannot be regarded as wastage because 1) it serves a useful function in the field, 2) it is recoverable for reuse in agriculture if not too salty, and 3) even if greatly degraded it can be drained to marshes for wildlife habitat or may be desalinized and reused if the Department of Water Resources' (DWR) desalting plant near Los Banos proves to be successful and economical.

Another difference among the various water agencies in the SJV is the method and amount of charge for water and its distribution. In general, agencies that distribute federal water charge lower rates (in terms of \$/AF) than those distributing state (SWP) water. However, in addition to the basic water cost, agencies must also levy a variety of other charges (often on a \$/ac basis) to cover costs of distribution, improvements, and overhead. In general, there is less incentive to use water sparingly when it is plentiful and cheap. In many instances in the SJV, however, water charges by the agency, along with associated on-farm costs of irrigation (energy, labor, etc.), plus the fact that surface water allocations are sometimes limited to 2-3 AF/ac, make it necessary for water users to show prudence in the amount and frequency of water application. While this may be less so in districts in the northeast part of the SJV, limited surface water supplies in the westside and southern parts of the SJV provide the major incentive for judicious water applications in irrigated agriculture.

Differences exist between and within districts in topographic, soil and water quality characteristics, and these determine the type of irrigation system and drainage requirements for each area. Local experience, rather than an irrigation system *per se*, determines the efficiency with which water is managed in relation to each of these variable characteristics while still maintaining crop yield and the long-term productivity of the land.

The development of dependable water supplies has enabled the SJV to become one of the world's leading agricultural areas in both quantity and variety of produce. Crop production means that water is consumptively used, i.e., irrecoverably lost to the air by evapotranspiration (ET). Seasonal ET varies from crop to crop, mainly because of the length of the growing season and the time of year that the crop is grown. Thus, small winter grains with a 182-day growing season have an ET of 16 inches, whereas summer-grown cotton with a 182-day season has an ET of 32 inches, but summer-grown pinto beans have an ET of 20 inches because they mature in only 107 days. Cropping patterns, however, are determined more by climate, soil adaptability and market factors than by seasonal consumptive use.

Agricultural Water Conservation

There is a large array of water conservation actions, but while these are workable in theory many are not always justified in practice because of technical, economic, and environmental reasons. Such conservation actions are generally taken during water storage, conveyance, and application, by use of cultural and crop management practices, by reusing and reclaiming water, and through institutional mechanisms.

Although some may disagree, California's foremost water conservation action is the storage of excess water runoff in reservoirs because this prevents considerable winter and spring runoff from rainfall and snowmelt to the Pacific

Ocean, from which water is irrecoverably lost. Some water is inevitably irrecoverably lost during conveyance by evaporation and by transpiration from riparian and phreatophytic vegetation. Except in heavy clay soils, lining canals increases conveyance efficiency. In most areas of the SJV, seepage and percolation losses are recoverable though usually at the cost of pumping energy.

Water applied to agricultural fields is largely lost irrecoverably by ET to the air. ET can be curtailed by reducing the area and/or the rate and/or the time duration of the ET surface. In California's irrigated agriculture E (soil surface evaporation) is usually the smaller component of seasonal ET, and its reduction is most practically achieved by preventing unnecessary wetting and exposure of the soil surface. Since E does not contribute directly to crop yield its curtailment would be useful, but for the magnitude of water that could be saved statewide, special efforts to reduce E are generally not worthwhile. Furthermore, reducing E can result in a greater partition of solar energy to water loss by transpiration.

Reducing crop transpiration reduces plant growth and thereby generally reduces economic yield. Reducing planted acreage will definitely curtail total T and make more water available for other uses, but this option would be detrimental to those in and associated with the agricultural industry and to consumers. Curtailing the rate of tranpiration by withholding some irrigation water or by treating active foliage with costly antitranspirant sprays would curtail the rate of transpiration but would, in most cases, reduce crop yield proportionately. Growing crops that mature in a shorter time would also reduce seasonal T, but if this enabled double-cropping instead of single-cropping annual T would be greater (and no water would be conserved). Gross crop production and gross farm income probably would also increase. Although there is a possibility of reducing both ET and yield to some degree without a loss in farm profit, the savings in water may not be worth the accompanying risk of over-stressing the crop.

During application of water "losses" to runoff and deep percolation (both of which are potentially recoverable) can be reduced in several ways which result in higher irrigation application efficiency. In most cases, although such reductions curtail farm water demand and deplete less water from surface and subsurface sources, there is a roughly equal reduction in return flows resulting in no *net* savings of water. A *potential* application efficiency that can be *realistically* achieved with any well managed system under most good field conditions is about 80%. Application efficiency can be low for any irrigation system if it is poorly designed and badly managed.

Irrigation scheduling programs (providing the right amount of water at the correct time to satisfy crop needs) are aimed primarily at improving crop performance by preventing 1) over-irrigation (that might drown the crop) or 2) under-irrigation (that stresses the crop). In the first case water savings are mainly of recoverable DP and RO, and in the second case, ET (irrecoverable) would actually be increased!

The reclamation (when needed) and reuse of agricultural, municipal, and industrial wastewaters is important because it reduces the demand on freshwater supplies and enables high basin efficiencies. However, unless that water would otherwise be lost to a sink from which it is irrecoverable, its reuse will not reduce net water demand for the state.

Greater use of brackish water has been suggested as a means of supplementing freshwater supplies to meet irrigation demands. In the long term, however, it will be necessary to 1) use freshwater supplies to maintain a salt balance; and 2) remove the salts from agricultural areas. M&I wastewater for irrigation is acceptable for use by farmers on some crops but only if the risk of using such water (as an alternative to developing freshwater) does not become the sole responsibility of the farmers. After all, the beneficiaries of such reuse include the farmers who need a supplemental water supply, the producers of wastewater who seek disposal sites, and the state which seeks to ensure adequate supplies of good quality water to meet numerous and varying demands.

A number of institutional mechanisms exist or have been suggested as a means of conserving or making more efficient use of water. The California Water Code specifies " reasonable use" of water and many water agencies have regulations, often strictly enforced, to ensure that users do not irrigate wastefully. Again, it must be remembered that in most cases "wasteful" irrigation results in recoverable RO and DP, so it is not that water is lost, but that energy and labor are used to recover avoidable water losses.

In California, there is no state-enforced regulation of ground water pumping. Surface water availability and economic factors determine the number of wells drilled and the depth to which pumping is affordable. Local management by users and agencies overlying a common aquifer is probably the most acceptable way of guarding against chronic overdraft. This management can be effective in the long term only if net demand (mainly irrecoverable ET loss from irrigated agriculture) does not exceed the firm yield (without overdraft) of the aquifer and the available surface water supplies. In the south SJV, there is clear evidence that local management by water agencies has reversed the trend of declining water tables by using imported surface water 1) to recharge the aquifers and/or 2) substitute for groundwater pumping. Thus, water transfers from areas of lesser demand to areas of greater demand can be a useful institutional mechanism for making efficient use of water. However, efficient use of water does not necessarily result in water conservation in the sense of reducing net statewide demand.

High water prices and other costs associated with irrigation undoubtedly provide an incentive to use water wisely, but there is as much incentive to conserve water if it is scarce even though it may be cheap. Thus, many economists believe pricing *per se* should not be used as a mechansim to induce conservation because it is the scarcity value of water, in a market of competitive demands for that water, which dictates how efficiently the water is utilized. Again, efficient use of water in response to scarcity value will not produce a net water saving unless it results in less irrecoverable outflow to the ocean and to the air.

Water Conservation by San Joaquin Valley Agricultural Water Users

It should be recognized that in the SJV, agricultural water conservation is not a new "fad," but has been a long-practiced necessity in many areas because water supplies are finite and in some years can become scarce and expensive to acquire. Some of the activities and concerns over misconceptions of conservation in the SJV were expressed and summarized in 1) the Proceedings of a Workshop on Agricultural Water Conservation held in Fresno on November 6, 1980, and 2) in Water Conservation Surveys by the Association of California Water Agencies. Present water conservation measures in SJV agriculture include: 1) improved land grading, 2) irrigation return flow systems and other water reuse, 3) pipelines or lined canals, 4) use of irrigation systems that have a high potential for efficiency when properly managed, 5) "demand" rather than "rotation" delivery of water, 6) field and weather measurements to enable correct scheduling of irrigation, 7) deep preirrigation during the period of surplus water and rain, and 8) phreatophyte and weed control.

Items 1-6 above will conserve water mainly by reducing recoverable water losses and/or by reusing recovered water, thus having little or no impact on *net* water supply. Items 7 and 8 are more likely to improve net supply because irrecoverable losses may be reduced. Thus, although a deep preirrigation usually has a low irrigation application efficiency, the storage of surplus water in the root zone and in groundwater prevents or reduces its possible irrecoverable loss a) by outflow to the ocean because of insufficient surface storage capacity, and b) by evaporation because evaporative demand is lower in winter and spring (preirrigation season) than in summer. The control of nonagricultural vegetation reduces irrecoverable transpiration (T) losses, but the magnitude of T loss from weeds and phreatophytes in the SJV is small compared to T losses from crops. However, growers are unlikely to take actions that reduce crop transpiration because of the accompanying risk of reducing crop yield.

Thus, although water is conserved on-farm and within districts by reducing recoverable water and by water reuse, there is little scope for realistically reducing *net* water demand in summer because of the adverse effect of reducing transpiration on crop production. However, in some areas of the southern SJV, water percolating to highly saline perched water tables or to "moisture deficient soils" is regarded as irrecoverable. Those percolation losses should, therefore, be avoided.

Associated Effects

There may be several effects (other than the saving of a quantity of water) associated with agricultural water conservation actions. These may be good (energy savings) or bad (less water contributed to groundwater recharge and to wildlife habitat), and may occur on-farm (less leaching of fertilizers) or off-farm (less pollution of waters receiving agricultural return flows).

Some advantages of reducing recoverable "losses" include: 1) energy savings by reducing pumping requirements both in supplying water to farms and in recovering the losses; 2) plant nutrient savings by reducing leaching losses; 3) less degradation of quality of surface and/or groundwater by reducing nutrient pollution, mass emission of salts, and plant disease and weed problems; 4) less standing water from runoff where mosquitoes could breed; and 5) increased in-stream flows in sectors of rivers when water diversions are reduced.

While measures for reducing recoverable water "losses" can reduce water-agency, irrigation-district, and on-farm delivery requirements, they do not reduce net water consumption of hydrologic basins. Disadvantages of reducing recoverable water "losses" include reduced water for leaching, for groundwater recharge, and for wildlife habitat.

Since the *reduction of irrecoverable ET* losses amounts to reduction in net water consumption, major advantages are reduced draft of surface and groundwater, increased streamflow, and additional water for other agricultural and M&I uses. Pumping requirements would be lower leading to a savings in energy and water costs. Water quality would be improved through greater solution of salts because less (pure) water is lost to the air. When a reduced ET rate results in fewer irrigations and reduced frequency of leaching loss there could be a savings of fertilizer nutrients and improved quality of subsurface water. Costs of implementing techniques for reducing ET can be a major disadvantage, but more importantly, reducing crop T will generally reduce crop yield. Large reductions of ET could affect microclimates by reducing humidity and increasing temperatures.

By intercepting water which would otherwise end up in "moisture deficient soil", brackish groundwater, salty lakes, or the ocean, the amount of water that can be reused is increased and thus on-farm and irrigation district delivery requirements are reduced. The disadvantages of intercepting these losses to saline sinks include: 1) the cost of techniques (e.g., tile drains) and pumping for reuse; and 2) loss of flow to the ocean and brackish sinks, thus interfering with ecological, navigational, and recreational uses.

Water Conservation vs Water Deficit

In the San Joaquin Valley, annual net water-demands are 14.0 MAF by agriculture plus 0.6 MAF by M&I uses. This 14.6 MAF net demand is met annually by net supplies of 7.2 MAF from local sources, 4.9 MAF from the CVP, 0.8 MAF from the SWP and 1.7 MAF by overdrafting groundwater aquifers. The present annual net water deficit in the SJV is represented by the 1.7 MAF overdraft. There are only three ways to overcome this deficit:

1) Reduce *net* water demand, i.e., reduce *irrecoverable losses*, mainly ET to the air. Since most of the irrecoverable agricultural water loss from the SJV occurs as ET and because ET reduction will often curtail agricultural production, this usually is not a practical solution. (Conservation actions that reduce only recoverable losses will *not* reduce the *net* water deficit.), or

2) Bring more water into the SJV by water development and water transfers from Northern California through completion of the State Water Project or public-supported systems or through private water sales in an open water market system. This alternative will come about only through rational discussion and compromise to overcome economic, environmental and institutional problems associated with interbasin water transfers, or

3) A combination of 1) and 2) above. That would be plausible only if it resulted in a) some reduced ET and crop yield but not in reduced farm profit (likely only when water and other irrigation costs are high); and b) water transfers that were of mutual benefit to those at the point of origin (sellers) and those who receive the water (buyers). Furthermore, the storage and transfer of surplus flood water (over and above that needed to maintain instream needs) that would otherwise be irrecoverably lost to the ocean would contribute considerably toward reducing California's projected net water deficit.

Water Conservation Potential in Statewide Perspective

Although an average of roughly 200 MAF of precipitation enters California each year, the total surface runoff for instream, agricultural, municipal, and industrial uses is only about 72 MAF plus about 6 MAF of inflow from Colorado River diversions and from Oregon. Groundwater pumping contributes about 16.5 MAF/yr, of which 2.3 MAF is overdraft and represents the state's present net water deficit. Of the 200 MAF of precipitation, about 150 MAF are lost to the atmosphere, roughly 120 MAF as evapotranspiration from forests and unirrigated rangelands and evaporation from lakes, and 30 MAF as ET from irrigated agriculture. About 50 MAF flow to saline bodies (mainly the Pacific Ocean) and to geological formations from which the water cannot be recovered. Thus, the total precipitation (200 MAF) is accounted for solely in terms of irrecoverable water losses (150 MAF to the air and 50 MAF to, mainly, the ocean). Obviously, then, if the state wishes to conserve water (i.e. reduce net depletion) it must curtail irrecoverable water losses to the air and to highly saline sinks. Such curtailment, however, only reduces demand but does not increase the total supply of water. This will, therefore, mean that the increasingly competitive demands for water can more readily be met each year, but it can entail some adverse effects associated with reducing certain irrecoverable losses and redistributing the saved water among competitive uses.

Although a wide range of estimates of potential "water savings" in California have been publicized, this report does not provide a precise numerical value for water conservation because:

1) A distinction must be made between water savings that occur only on-farm and those that, because they occur on a basin/statewide basis, will help alleviate the state's net water deficit; and

2) Increasingly competitive water demands and allowance for extended droughts can only be met by reducing irrecoverable water outflow to the air as ET and to saline sinks (mainly the ocean, as by water storage projects), but there is insufficient information on the economic and environmental impacts of reducing those irrecoverable water losses from the state.

Until the above points are clarified by additional analyses, it is impossible to actually quantify the water savings that will truly reduce the state's present and projected net water deficit. However, in the light of the concepts presented in this report, the following conclusions can be made:

1) The often-heard claims of achieving a 10%-50% saving in agricultural water use are unrealistic as a means of reducing the state's net water deficit because they usually fail to distinguish between recoverable and irrecoverable water losses and thus include water that is available for reuse.

2) Only by reducing the irrecoverable water losses can the state's net water deficit (presently represented by about 2.3 MAF of groundwater overdraft) be decreased in the absence of importing new water supplies.

3) In the San Joaquin Valley's agriculture, these irrecoverable losses go mainly to: a) the air as ET (mainly crop transpiration) and b) highly saline water tables. Some consider percolation into presently "moisture deficient" subsoils as irrecoverable because years will be required to saturate this material before percolating water could be recovered. Because the area of such soils now irrigated in the San Joaquin Valley is limited and deep percolation observed on such soils is small, these losses are of lesser importance.

4) If crop production is to be maintained, reductions in ET losses are feasible only as reduced evaporation (E) losses.

5) The realistic potential for reducing E and flows to highly saline water tables probably approximates 2% to 3% of the water applied in agriculture, but the technical and economic feasiblity of achieving even this reduction needs to be explored, including an assessment of whether E savings will be later partially lost as transpiration.

6) Therefore, the state's net water deficit, mainly overdrafting of groundwater in the San Joaquin Valley, cannot be offset solely by agricultural water conservation if crop production is to be maintained at present economic levels.

CONCLUSIONS

Because California's water issues, including conservation of agricultural water, are multifaceted, this report necessarily covers numerous aspects, some in detail and some superficially. However, the following principal conclusions can be distilled from the volume of material presented:

1. Within a crop season, water used in irrigation is either *recoverable* or is *irrecoverably* lost. It is important that recoverable water be recovered and reused as efficiently as possible. However, it should not be permitted to accumulate under conditions where it is subject to evaporation or to transpiration losses by nonproductive vegetation. Furthermore, if seepage, surface runoff, and deep percolation make contributions to soil moisture available to crops, groundwater, or wildlife habitat and recreation, that water cannot be regarded as lost. High priority should be given to preventing water flow to highly saline sinks both inland and to the ocean because such losses are irrecoverable. However, conservation decisions must take into account environmental and instream needs as well as the appropriate balance of potential water savings against net farm income, possible reductions in food and fiber production, infrastructural viability, and the ability of farmers to retain flexibility in their operations and remain competitive in the market.

2. Much of California's irrigation water is distributed through water agencies such as irrigation districts. Each district is unique in its historic, geologic, geographic, water-source, political, and other characteristics. Therefore, water pricing, management, and distribution policies vary considerably from district to district. Because of these unique characteristics, universal recommendations on agricultural water conservation actions cannot be made.

3. There is a large array of water conservation actions, but while these are workable in theory many are not always justified in practice because of technical, economic, and environmental reasons. These conservation actions might be taken during water storage, conveyance, and application; by use of cultural and crop management practices; by reusing and reclaiming water; and through institutional mechanisms.

4. In much of the San Joaquin Valley, water conservation has been practiced by water agencies and growers for many decades. This has been done out of necessity because of poor natural distribution of water and scarcity of water supplies relative to irrigation demands. Irrigation is essential because available water is the major resource lacking in an otherwise bountiful valley blessed with fertile soil and plentiful solar radiation. The findings of this report are in general agreement with the principal conclusions in the "Summary of Proceedings of the Workshop on Agricultural Water Conservation, An Update with Emphasis on Conditions in the San Joaquin Valley," sponsored by the California Water Commission, DWR, and the SJV Agricultural Water Committee.

5. If water saving is looked at solely from an on-farm viewpoint (without regard to associated effects), the decision to use water conservation measures

depends on whether the motive is 1) just to reduce on-farm water demand, or 2) to reduce the state's net water deficit. Reducing field runoff (RO) and deep percolation (DP) by improving irrigation application efficiency, will reduce on-farm water demand but will not affect the state's water deficit because RO and DP are recoverable for reuse. The state's water deficit can only be reduced by curtailing irrecoverable losses to the air and to saline sinks, mainly to the ocean. This will not create new water, but it will make more of the existing water supplies available for agricultural, M&I, and instream uses.

6. On-farm water savings can best be achieved by proper *management* of existing and new irrigation systems and through good irrigation scheduling programs which determine the correct timing and quantity of water application. These savings will mainly occur as a reduction in recoverable water and as reuse of recovered water. On-farm reduction of irrecoverable water loss can be achieved without curtailing economic crop production, mainly by reducing soil-surface evaporation (E), but the magnitude of the state-wide savings that can be practically achieved through reduced E is not expected to be substantial.

7. The largest true loss of water from agricultural areas occurs as crop transpiration (T) which can theoretically be curtailed only by reducing the area, the rate and/or the time duration of the transpiring surface. Because of the strong relationship of crop growth to T, reductions in T by restricting irrigation, if considerable, would clearly reduce crop production, and if small, may cause only a small reduction in crop yield but would increase the risk of substantial reductions in yield. Neither prospect is likely to be acceptable to growers. They are more likely to take water conservation actions, however, if their net farm profits increase through savings in production costs associated with water management. This could mean replacing the goal of yield maximization with a goal of profit maximization, but the quantity of water saved may be small at present water and production costs and crop values.

8. Apart from crop yield loss, likely to occur by reducing irrecoverable transpiration losses, there are many other effects associated with agricultural water conservation actions. These may be good (e.g., energy savings) or bad (e.g., less water contributed to groundwater recharge and to wildlife habitat), and may occur on-farm (e.g., less leaching of fertilizers) or off-farm (e.g., less pollution of waters receiving agricultural return flows).

9. In the San Joaquin Valley, the present annual net water deficit is represented by a 1.7 MAF overdraft. There are only three ways to overcome this deficit:

a. Reduce *net* water demand, i.e., reduce *irrecoverable losses*, mainly ET to the air. Because ET reduction will usually curtail agricultural production, this generally is not a practical solution.

b. Bring more water into the SJV through water development and/or water transfers from Northern California through public-developed systems or through private water sales in an open water market system.

c. A combination of a) and b) above.

To be practical, these solutions should result in little loss in farm profit, and water transfers should be of mutual benefit to the water sellers and the water buyers. The storage and transfer of surplus flood water (over and above that needed to maintain instream needs) that would otherwise be irrecoverably lost to the ocean would contribute considerably toward reducing California's total projected net water deficit. Also, increased storage, both as surface and groundwater, would reduce the state's vulnerability to future droughts.

10. Although several estimates of potential "water savings" in California have been publicized, this report does not provide a precise numerical value for conservation because: a) a distinction must be made between water savings that occur only on-farm and those that help alleviate the state's water deficit; and b) that deficit can only be met by reducing irrecoverable water outflow, but there is insufficient information on the economic and environmental impacts of reducing those irrecoverable water losses from the state.

11. It is erroneous to conclude that a particular irrigation system such as sprinkler or drip requires only a fraction of the water applied by systems such as furrow or border-strip. (With good design and management, most irrigation systems have a similar potential for efficient water application.) Because of the recoverability and reusability of field runoff and deep percolation, it is even more erroneous to conclude that decreasing runoff and deep percolation will proportionately reduce the state's *net water deficit*. Therefore, statements suggesting a 10-50% potential savings in agricultural water conservation by improving irrigation application systems are a disservice to the people of California because water policy and action programs based on such statements will substantially underestimate the state's needs for future water supplies.

12. Because only reductions in irrecoverable (rather than recoverable) water losses have an impact on the state's net water balance, and because crop transpiration (T) cannot be greatly reduced if agricultural production is to be maintained, the state's net water deficit can be reduced only by agricultural water conservation actions that curtail a) soil surface evaportation (the E component of ET) and b) flows to highly saline sinks. Therefore, the realistic potential for agricultural water conservation, without loss in crop production, is not likely to be in the range of 10-50%, but is more likely to be approximately 2-3% of the water applied in California's irrigated agriculture. This estimated percentage saving is similar to the percentage saving calculated from figures published in the State Department of Water Resources Bulletin 198 (1976) on Water Conservation in California.

13. A savings of about 2% of the state's water applied to agriculture conserves only approximately 0.65 MAF, an amount that alone is insufficient to meet California's current net deficit of 2.3 MAF, now reflected as groundwater overdraft.